DRAFT TECHNICAL MEMORANDUM

IN-DELTA STORAGE PROGRAM SEEPAGE CALIBRATION STUDY

Prepared for

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1.0 BACKGROUND AND PURPOSE

Reservoirs at Webb Tract and Bacon Island are expected to have the potential for changing seepage conditions within neighboring islands where the slough widths are relatively narrow. Changes in the seepage conditions and measures to mitigate those changes have been previously estimated (URS, 2003a). In June 2004, a failure of the Middle River levee on Upper Jones Tract resulted in flooding of Upper and Lower Jones Tracts. Seepage was observed in adjacent islands as a result of the flooding. Four piezometers were installed at McDonald Island on a portion of the Empire Cut levee for the purpose of monitoring seepage conditions during pumping of Lower and Upper Jones Tract.

The objective of this study is to calibrate seepage models developed for the In Delta Storage Program (URS, 2003a) by modeling seepage conditions at McDonald Island during flooding of Lower Jones Tract and comparing them with the observed conditions. In addition to the calibration of the seepage models, laboratory test data for samples of the sand layer underlying the peat obtained at Webb Tract and Bacon Island during previous investigations were reviewed with respect to the variability in permeability that might be anticipated along the perimeter of the embankments.

The purpose of this technical memorandum is to present the results of the seepage calibration study and sand layer data review.

2.0 APPROACH

The computer program SEEP/W (Geo-Slope International Ltd., 1994) was used to estimate seepage conditions through a transverse section of the existing levee at McDonald Island. The SEEP/W model was developed using geotechnical information obtained during the piezometer installation (Lowney Associates, 2004). The calibration study was performed as follows:

1. Estimate total head conditions prior to flooding.
2. Compare the model results with piezometric observations obtained after pumping of Lower Jones Tract was completed when piezometric levels at McDonald Island were stabilized.
3. Adjust the boundary conditions or soil properties, if necessary, to calibrate the model with observed piezometer response.
4. Estimate total head condition with Lower Jones Tract flooded.
5. Compare model results with observed piezometric response.
6. Adjust boundary conditions or soil properties, if necessary, to calibrate the model with observed piezometer response.

7. Comment on model results and their applicability to seepage models for In Delta Storage Program (URS, 2003a).

3.0 METHODOLOGY

The computer program SEEP/W was used to estimate seepage conditions. SEEP/W uses a two-dimensional finite element method to model seepage conditions and assumes that flow through both saturated and unsaturated media follows Darcy's Law. The seepage analyses were conducted considering steady-state conditions.

Boundary conditions used in the model were the same as in the In Delta Storage Program seepage models (URS, 2003a). Fixed boundary conditions were used to model constant reservoir and slough heads and far-field groundwater levels. Other portions of the levee and ground surfaces on the islands were modeled using an unrestricted, free-flowing boundary condition; that is, a boundary condition that is determined at each node by SEEP/W during the analysis of flow conditions. The bottom of the cross-section was modeled as a no-flow boundary.

The SEEP/W analysis program was used to evaluate the steady-state phreatic surface location and the total head distribution throughout the model. The SEEP/W contouring program was used to generate total head distribution diagrams.

4.0 ASSUMPTIONS

The following assumptions were used in the analysis:

- The flood elevation for Lower Jones Tract is 1.5 feet.
- The peat and sand stratigraphy at McDonald Island is based on Borings EB-3 and EB-4 (Lowney Associates, 2004).
- A clay layer is assumed to underlie the sand at elevation –70 feet similar to previous analyses (URS, 2003a.)
- The stratigraphy at the adjacent Lower Jones Tract levee is assumed to be the same as at McDonald Island.
- A three-foot thick layer of silt is assumed at the bottom of Empire Cut.
- The slough geometry of Empire Cut was based on 1999 survey data provided by the Department of Water Resources.
- The water level in the interior of McDonald Island was assumed to be –22 feet at a distance of 1,500 feet from the levee. This assumption is based on the proximity of a deep drainage ditch located to the northeast of the site and the water level in interior sloughs estimated from USGS quadrangles (Woodward Island, 1978 and Holt, 1994).
- The coefficients of permeability used in the model are as shown in Table 1.

Table 1
Permeability of Soil Units

Layer	Vertical Permeability k_y (cm/sec)	Horizontal Permeability k_x (cm/sec)	k_y / k_x
Levee Clay [1]	$1.0x10^{-5}$	$1.0x10^{-4}$	0.1
Silt	$1.0x10^{-6}$	$1.0x10^{-6}$	1.0
Peat [2]	$2.0x10^{-5}$	$2.0x10^{-4}$	0.1
Sand [3]	$1.9x10^{-3}$	$1.9x10^{-2}$	0.1
Lower Clay [1]	$1.0x10^{-6}$	$1.0x10^{-6}$	1.0

[1] URS, 2003a.
[2] Vertical permeability from URS, 2003a. k_y / k_x used in URS, 2003A was 200.
[3] Based on gradations of samples from EB-3 and EB-4 using Hazen's equation.

5.0 RESULTS

Phreatic surfaces and total head contours (in feet of water) estimated by the seepage model are presented on Figure 1. Figure 1A shows the estimated total head conditions prior to flooding and Figure 1B shows the total head conditions after flooding of Lower Jones Tract. As shown on Figure 1, flooding of Lower Jones Tract would result in a 7.7-foot increase in head under the interior toe of the McDonald Island levee (at location of Boring EB 4) and flooding of a zone 300 to 400 feet wide adjacent to the levee toe. Table 2 compares the total head estimated at EB-3 and EB-4 by the seepage model with the total head observed at piezometers EB-3 and EB-4 as provided by DWR.

Table 2
Total Head Conditions

Condition	Seepage Model	Observed
Pre-Flood		
EB-3	-16.5	-17 [1]
EB-4	-17.0	-17 [1]
During Flood		
EB-3	-7.8	-8.5 [2]
EB-4	-9.3	-9.5 [2]

[1] Pre-flood conditions assumed to be similar to those observed after 12/6/05 when piezometric heads stabilized after pumping of Lower Jones Tract.
[2] Lowney Associates (2004).

Table 2 indicates that the total head conditions estimated by the model are in close agreement with the observed total head conditions for both the pre-flood and flooding case.

The model was also checked assuming the far-field boundary condition at the neighboring island under existing conditions as a groundwater level at about 2 feet below the average ground elevation of McDonald Island as was done for the In Delta Storage Program seepage models. In addition, the ratio of the vertical and horizontal permeability for the peat was changed to 0.005 as was used in the In Delta Storage Program seepage models. The estimated change in total head at the interior toe of McDonald Island was similar.

The results of the seepage calibration study of McDonald Island confirm that the seepage models developed for the In Delta Storage Program provide a reasonable estimate of the total head conditions that would result from water storage in Webb Tract and Bacon Islands.

6.0 SAND LAYER VARIABILITY AT BACON ISLAND AND WEBB TRACT

Laboratory test data for sand layer samples obtained at Webb Tract and Bacon Island during the previous geotechnical investigations were reviewed for the range of variability in permeability that might be anticipated. The data available to us was limited to samples from six borings along the perimeter of the levees and 13 boring located within the islands. Within the interior of the islands, the data were for samples of the upper few feet of the sand layer. The data are summarized in Table 3.

Table 3
Range of Permeability of Sand Layer

	Number of Locations	Range of Soil Classification	Range of Percent Passing #200 Sieve	Reference	Range of Permeability (cm/sec)
Bacon Island	8	SP to SM	2 to 47	URS, 2003b DWR, 2003	$1x10^{-2}$ to $1x10^{-5}$
Webb Tract	11	SP to SM	4 to 38	URS, 2003b HLA, 1990 DWR, 2003 URS, 2004	$1x10^{-2}$ to $1x10^{-5}$

Descriptions of soils found in several borings around the perimeter of the Webb Tract and Bacon Islands were also reviewed. Generally, the sand layer underlying the levees of both islands is described as a silty sand.

7.0 CONCLUSIONS

A seepage calibration study was performed using data collected from the Empire Cut levee at McDonald Island, where seepage was observed in the island interior (adjacent to Lower Jones Tract) as a result of the Jones Tract flood event. The seepage model, which was developed in a manner similar to the models used for the In Delta Storage Program, was able to estimate the seepage conditions that were observed. Therefore, we have concluded that the seepage calibration study validates the approach used in the In Delta Storage Program seepage models and that those models provide a reasonable estimate of the average seepage conditions for the proposed Webb Tract and Bacon Island reservoirs.

Actual seepage conditions will vary at any section along the reservoir embankments based on many factors including (1) thickness of the peat and sand units; (2) variations of soil type within the existing levee, peat, and sand units; (3) phreatic surface within the neighboring islands; and (4) distance of the neighboring island from the embankments. Laboratory data reviewed for the sand layer at Bacon Island and Webb Tract indicates that there are likely to be areas where the permeability of the sand unit can be anticipated to be similar to that found at EB-3 and EB-4.

However, the locations of the borings for the data available to us were primarily located within the island interior and thus we are unable to comment on where areas of the sand layer would have higher permeability under the Webb Tract and Bacon Island levees.

8.0 REFERENCES

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